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The Economic Effects of Reallocating Publicly Owned Hydropower in New York State

by

Thomas W. Hertel

and

Timothy D. Mount*

Department of Agricultural Economics
Cornell University Agricultural Experiment Station
New York State College of Agriculture and Life Sciences
A Statutory College of the State University
Cornell University, Ithaca, New York 14853

I. INTRODUCTION

In a July, 1981 report to the Governor and the State Legislature, the Chairman of the Power Authority of the State of New York (PASNY) proposed a substantial reallocation of cheap, state-owned hydropower among residents of the state. Referring to the current allocation of hydroelectricity, PASNY Chairman John Dyson asserts that: "such inequitable treatment of citizens by a State agency . . . is, in our opinion, intolerable in a democratic society." For purposes of illustration, Dyson (1981) notes that the cost of 700 kwh of electricity in Plattsburgh is $11, as opposed to $86 in White Plains. His proposal for reallocating hydropower benefits involved the establishment of a Residential and Rural Energy Authority which would distribute the inexpensive hydropower remaining after industrial committments to "each New York family in an equal and just manner." (The industrial committments are those necessary to maintain an estimated 100,000 jobs in Upstate New York, the existence of which is purported by PASNY to be attributable to historically cheap power.)

The hydropower facilities operated by PASNY currently generate electricity at a cost of only 0.5 cents per kilowatt hour (Dyson, 1981). This contrasts sharply with the cost of generating electricity from petroleum, which is the marginal source of power for New York State. Fuel costs alone for oil-generated electricity amount to 6 cents per kwh (Dyson, 1981). Thus the economic rents associated with these facilities amount to approximately $1.5 billion per year. This translates into about $250 per residential electric customer (annually).[1] Since PASNY sells the hydropower at cost these economic rents are passed on to electricity customers.[2]

Table 1 summarizes where PASNY's hydropower goes. While thirteen percent is sold directly to the aluminum industry, the bulk of this power is transferred to the ultimate customers via municipals and cooperatives or investor-owned utilities. Of the hydropower remaining in the state, 58.3% ends up in the industrial sector, while 41.7% goes to residential and commercial uses. Thus, in addressing only allocations to the residential sector, the PASNY proposal did not suggest altering the majority of the state's committments. However the report leaves

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[1] Nameplate capacity of PASNY's facilities at Niagara Falls and Massena combined amounts to 3,102 megawatts or approximately 20% of the state's capacity. Ignoring capital costs associated with these facilities, multiply the difference in fuel costs (6 cents/kwh) by the amount of hydropower generated each year to arrive at this total. The long run value of these economic rents will be of the same order of magnitude, since the cost of incremental capacity to generate electricity from coal is approximately equal to the variable costs of oil-fired plants.

[2] Enabling legislation requires PASNY to sell the hydropower at the "lowest possible cost". It should be noted however, that Longshore (1981) found this not always to be the case in practice.

Table 1. The Allocation of Hydropower in New York State

Contracts	$ of Subtotal	Kilowatts	% of Total
Contracts with industry		386,000	12.9
ALCOA	45.1		5.8
Reynolds	51.8		6.7
CMC	3.1		0.4
Sales to municipals and co-ops (1979)		547,200	
Ultimate Use:			
Residential	40.		7.3
Commercial	20.		3.6
Industrial	40.		7.3
Contracts with Upstate utilities*		1,829,982	60.8
Ultimate Use;			
Residential	45.1		27.4
Industrial	54.9		33.4
Sales out-of-state		245,000	
Total		3,008,000	100.0
(nameplate capacity)		(3,102,000)	

* Niagara Mohawk (1,257,432 kw), NYSEG (422,550 kw), Rochester G & E (170,000 kw).

Sources: Dyson, 1981 and private correspondence with PASNY.

little doubt that electricity pricing in New York State is viewed as an important instrument of public policy.

What advice can the economist lend policy makers considering the problem of what to do with the state's hydropower? This paper develops an empirical model of New York designed to enable a comparison of alternative allocations of the economic rents associated with this natural resource. Particular emphasis is placed on hydropower currently allocated to industry. By taking a general equilibrium approach both direct and indirect effects of alternative allocation schemes are captured. The model is calibrated for 1977, based on the most recent data available. Simulation results indicate that several policy alternatives exist which would prove more effective in promoting any one of a number of distinct state policy objectives, including: increased income, employment, manufacturing output, and electricity conservation.

II. WHY GENERAL EQUILIBRIUM?

Because the economic rents from the state's hydropower are passed through to a subset of customers, they result in divergent average prices paid for electricity. Table 2 provides 1977 price data for five groups of electricity users. Even after adjusting for cost of service differentials, chemicals and primary metals appear to pay substantially less for their power. They are of special interest due to their intensive use of electricity, consuming 38% (1977) of the total demanded by New York manufacturing. Other (relatively electricity extensive) manufacturing pays less, in turn, than residential and commercial users. Thus the current allocation of hydropower may be roughly characterized as one in which electricity intensive users receive a large share of the rents, in the form of lower average prices.

A general equilibrium approach to the analysis of this differential pricing of electricity in New York State was selected in deference to extensive work in the field of public finance.[3] This research illustrates that partial equilibrium analysis of partial factor subsidies (i.e., they do not apply to all factors equally) can lead to seriously faulty conclusions. Harberger's (1962) use of a two sector, two factor general equilibrum model to analyze the economic effects of the corporate income tax is a "classic" in this area. Like later applications in areas such as property taxation (Miezskowski, 1972) and the preferential treatment of household production (Boskin, 1973) this general equilibrium analysis has led to some useful insights.

A simple diagram captures the essence of these models. Consider the case of an economy divided into two sectors: one which is energy intensive (I), and one which is energy extensive (X). The derived demand schedules for energy resources (R) in both sectors are provided in Figure 3. Assume that the price in initial equilibrium is P_R, while equilibrium quantities are given by R_I and R_X. Consider first the effect of introducing a partial factor subsidy amounting to $Q per unit of R employed in sector I. This subsidy lowers the effective price of R facing the firms in sector I, which encourages them to employ more of that input. If the supply of R to sector I were perfectly elastic, then the new price of R to this sector would be $P_R* = P_R - Q$, resulting in R_I* of the input being utilized.[4] This exogeneity of factor prices is precisely what is assumed when partial equilibrium analysis is conducted.

What if the supply of energy in this economy is fixed? Then any additional units of R employed in sector I must be bid away from

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[3] This work built upon earlier research in the theory of international trade (e.g., Stolper-Samuelson, 1941).

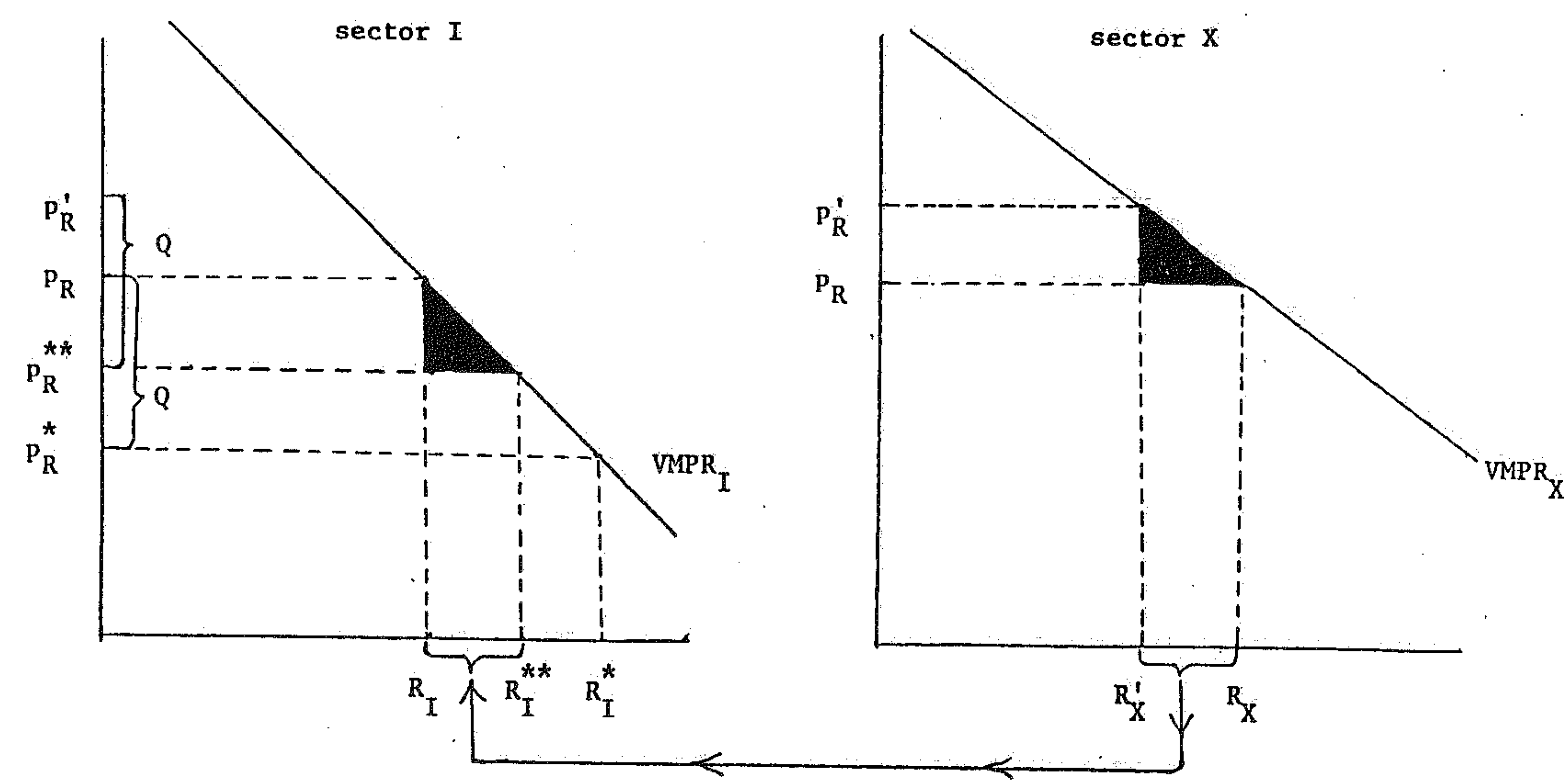
[4] For the purposes of this diagram, it is assumed that the value of marginal product for R in each of the sectors is independent of the amount of other inputs employed. This means that the derived demand schedules do not shift in or out in response to the movement of these other factors between sectors.

Table 2. Average Electricity Prices, by Sector: New York State, 1977 in $/kwh

Sector	Actual	Adjusted for Cost of Service Differential***
Commercial (Small light & power)	0.061*	0.039
Residential	0.059*	0.037
Electricity Extensive Manufacturing	0.030**	0.030
Chemicals	0.018**	0.018
Primary Metals (Primary non-ferrous)	0.012** (0.006)**	0.012

Sources: * Edison Electric Institute.
** Annual Survey of Manufacturers.
*** A transmission and distribution cost of service differential was computed by Baughmann and Bottaro (1976). It measures the differential cost of servicing small power and light customers vs. large power and light customers for the Middle Atlantic States. In 1972 this was found to be $0.15/kwh of electricity delivered. In 1977 dollars this amounts to $0.22/kwh, which was deducted from the average price paid by the residential and commercial sectors in order to arrive at the adjusted figure. This permits comparison prices paid across sectors.

Figure 1 Impact of a Partial Factor Subsidy



competing uses in the rest of the economy. The curve in the second graph provides a measure of the value of incremental units of the energy resource in the production of X. Assuming that R is perfectly mobile between the two sectors, an equilibrum will be reached when the presubsidy price of R rises to P_R'. The result of the subsidy is to shift $(R_X - R_X') = (R_I^{**} - R_I)$ units of the resource from sector X to sector I. This is strictly a general equilibrium effect.

From the point of view of economic efficiency, it is clear that the subsidy has driven a wedge between the marginal value product of R in the two sectors. The excess burden associated with this type of distortion has been approximated by Harberger (1962) as the area of the two shaded triangles. Perhaps more influential are the conclusions which can be drawn regarding the incidence of the subsidy. Since the price paid for the natural resource input rises in both sectors, all owners of natural resources benefit from the subsidy, not just those in the subsidized sector (I).

Up until this point the impact of the subsidy on other factors of production has been ignored. If it is assumed that these other factors have been lumped together into the aggregate input N, this means that these other factors are constrained to be substitutes in production (in the Hicks-Allen sense) with the natural resource input (R). Thus a decrease in the price of R facing firms in sector I will lead to a drop in the intensity with which N is utilized. As the price of R facing firms in sector X rises (assuming a fixed supply of R), they will substitute away from it. Abstracting from changes in the composition of output in the economy, a movement of factor N from sector I to sector X is expected. Assuming factor markets clear, P_N will be forced to adjust in order to equate the release of factors from I to their absorption in X.[5] This represents yet an additional dimension of the incidence problem. Not only does the partial factor subsidy on R in sector I affect the rate of return on R in sector X, it also affects payments to other factors of production.[6]

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5 Note that the change in P_N would be even larger if the price of the natural resource (P_R) were fixed exogenously. In addition, it is clear that this factor incidence effect is eliminated if P_N is fixed exogenously.

6 This analysis has abstracted from the impact of these factor price changes on the composition of output in the economy. In order to introduce commodity markets it is necessary to turn to the well-known mathematical formulation of the 2 x 2 model. Qualitative results developed by Jones (1965) demonstrate the important role played by elasticities of substitution in production and relative factor shares in determining the likely effects of factor subsidies. In the case of a partial factor subsidy on the natural resource input in sector I (the resource intensive sector), the direction of the resulting output effect cannot be determined. However, the impact on relative factor returns is unambiguous. The price of natural resources rises relative to the price of other factors of production (Hertel, 1983a).

After developing the computable general equilibrum model in Sections III and IV, we will draw on this qualitative analysis of partial factor subsidies in the interpretation of simulation results.

III. MODEL DESCRIPTION

The empirical model of New York State consists of six sectors, four primary factors of production, and intermediate inputs. Three of the sectors summarize manufacturing activity in the state. These are: primary metals (P), chemicals (C), and other manufacturing (X). The first two are of special interest due to their intensive use of relatively inexpensive electricity discussed above. Non-manufacturing activity is divided into three sectors: agriculture and non-energy mining (A), wholesale/retail activity (W), and a residual category (O) (finance and insurance, real estate, construction, non-energy utilities, transport and government enterprises). All of these are assumed to pay the same (commercial/non-subsidized) rate for electricity.

The four primary factors of production are capital (K), labor (L) and an energy resource aggregate (R), consisting of electricity (E) and purchased fuels (F) (see, for example, Fuss, 1977). The first two factors (K and L) are assumed to be in fixed supply, while the prices of the two energy inputs are determined exogenously by national fuel costs.[7] (Marginal electricity output comes from under-utilized, oil-fired plants, so that the price of electricity is tied to the price of imported fuel.)

Aggregate Production Structure and Industry Behavior

There are both theoretical and empirical issues involved in specifying sectoral production functions. Due to the difficulty of obtaining observations on inter-industry transactions, it is customary to resort to an input-output table in handling the sectoral demand for intermediate inputs (e.g., Fullerton, *et al*., 1978). However, fixed coefficients are excessively restrictive for primary inputs. Accordingly, the assumption of weak separability of primary factors from intermediate

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[7] In order to treat the energy inputs as primary factors of production, several important assumptions are required. First, it is assumed that the capacity for generating electricity is fixed in the short-run, and that at the margin, electricity in the state is generated from oil-fired facilities. Since there is currently substantial excess capacity in the electric utility sector, it is further assumed that the short-run, marginal cost of additional power is approximated by the cost of the petroleum required to generate it. But New York imports virtually all of the purchased fuels (coal, oil and natural gas) that it consumes. Treating the processing and delivery of these fuels as a simple mark-up over the cost of the raw fuel, it can be assumed that the price of purchased fuels is fixed exogenously. The infinitely elastic supply of fuel means that, in the short run, the marginal cost of generating electricity is constant. Assuming constant distribution costs, the price of electricity may be fixed exogenously. As their production is assumed to place no additional demands on state factor markets, electricity and purchased fuels become primary factors of production. This means that the processes by which these inputs are produced and delivered to customers may be ignored.

inputs is made, and this is a sufficient condition for the existence of a primary factor aggregate. The latter may be expressed as: $N = N[K, L, R(E,F)]$, where R is the function defining the energy resource aggregate. It will be assumed that N exhibits constant returns to scale.

The fixed coefficient production function for sector P, with the primary factor aggregate imbedded, can be expressed as:

$$\text{Output} = \min[N_P(K_P,L_P,R_P),(\frac{1}{a_{MP}})X_P,(\frac{1}{a_{CP}})C_P,(\frac{1}{a_{PP}})P_P,(\frac{1}{a_{AP}})A_P,(\frac{1}{a_{WP}})W_P,(\frac{1}{a_{OP}})O_P].$$

Output is a function of the primary factor aggregate N_P, and the intermediate inputs from sectors X, C, P, A, W, and O, none of which may be substituted for one another. The a_{ij}'s are fixed input-output coefficients, and the primary factor aggregate has been scaled such that one unit of this aggregate is required to produce one unit of output.

Dual to this fixed coefficient production function is a unit cost function which is independent of output under constant returns to scale. Cost minimization may be separated into three discrete steps. First, the sector selects a cost minimizing combination of electricity and purchased fuels to be employed in the energy aggregate: $p_R = p_R(p_E, p_F)$. The second step involves the choice between K, L, and R in the primary factor aggregate. This unit cost function may be written as:

$$c_P = c_P[p_K, p_L, p_R(p_E, p_F)].$$

At the third, and final stage of cost minimization, substitution among inputs is not permitted and the resulting cost function is additive.

Of the six productive sectors in this model, four (A, O, W, and X) are assumed to exhibit zero profits. However, primary metals and chemicals are national, oligopolistic entities and may thus have non-zero profits. It is hypothesized that the equilibrium price and output in these markets are determined nationally, and are essentially exogenous to New York in any given year. Furthermore, it is assumed that they have chosen to produce a portion of this output in the state precisely due to the accessibility of cheap, reliable electric power. It is absolutely essential that the model capture this locational flexibility, because one of the main arguments against raising electricity rates in these sectors is that the locational process will work in reverse. That is, marginal production, and eventually entire firms, may be shifted out of the state.

Output Determination in Primary Metals and Chemicals

In order to estimate the sensitivity of output allocation, in the primary metals and chemicals sectors, to unit production costs, a mathematical formulation was sought which would predict each state's share in national output. In addition, it is desirable that the model logically preclude negative shares. One appropriate formulation is provided by the logistics function (Berkson, 1944; Theil, 1969) where each state's share of national output may be expressed as a function of its unit cost of production relative to those of all other states in the sample.[8] Formally, this may be expressed (for primary metals) as:

$$S_i = P_i/P_{US} = \frac{e^{f_i^*}}{(1 + \Sigma_k e^{f_k^*})}$$

$$f_k^* = AP_k^* + BP \ln(c_k) \qquad k = 1, 2, \ldots, n, \text{ous}.$$

Here, P_i and P_{US} represent output in the primary metals sector in state i, and the entire U.S., respectively. The logistics function is used to approximate state i's share in national output (S_i), and the indices (f_k^*) are linear functions of the logarithm of each state's unit production costs. The data set consists of n states, and the rest of the U.S. (ous).

By defining the rest of the U.S. as the base region and setting:

$$f_i = f_i^* - f_{ous}^* = (AP_i^* - AP_{ous}^*) + BP(\ln (c_i) - \ln (c_{ous})),$$

the indices become:

$$f_i = AP_i + BP \ln (c_i/c_{ous}), \text{ for } i = 1, \ldots, n.$$

Furthermore, by considering the ratio S_i/S_{ous}, denominators cancel. In logarithms, the model may be expressed as:

$$\ln (S_i/S_{ous}) = \ln (P_i/P_{ous}) = AP_i + BP_i \ln (c_i/c_{ous}).$$

Note that c_i represents the minimum unit cost of production, given factor prices in state i. Because disaggregate intermediate input costs are not available at the state level, estimation of the model will require that c_i be a function of primary factor prices alone. (These are the prices which will be varied in the course of the policy simulations in Section V). The assumption implicit in this specification of the oligopolistic models is that the relative costs of intermediate inputs (between states) do not change.

Finally, note that cost minimization in the oligopolistic sectors occurs at the state level, while price determination is a national phenomenon. This means that state level profits and losses will exist, even in the long run. These profits and losses in sectors P and C are

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8 Baughmann, et al. (1979) utilized the logistics function in a similar context. Rather than "sharing out" a primary factor aggregate, they allocate a national energy aggregate to individual states, based on relative energy costs.

assumed to be absorbed by the national entity, thus eliminating any question of their distribution among economic actors in New York State.

Model Structure

Having settled on a structure for each of the productive sectors, the next task is to outline the manner in which they are linked together in a general equilibrium model. There are four sets of equations in the model outlined in Figure 1. The first group (A) describes the relationship between factor intensities and factor prices. These equations are independent of output levels because constant returns to scale are specified. Since only four of the six sectors are perfectly competitive, there are four zero profit conditions in this model [equations (1)-(4)]. The existence of an energy resource aggregate in each of the sectors (P_{Rj}) is reflected in the next six equations. Note that, even if the prices of electricity (P_E) and purchases of fuels (P_F) are equal in each of two sectors, there is no reason to believe that the prices of the respective aggregates will be equal. The latter will depend on the mix of the two energy inputs used in each sector.

Equations (11) through (16) are the unit cost functions associated with each of the six primary factor aggregates. Differentiation of these with respect to factor prices gives the intensities with which each factor is employed in this aggregate. The mix of energy inputs employed in the energy resource aggregate is found by taking the derivative of the latter with respect to the price of an individual energy input. The overall intensity of electricity (a_{Ej}) is found by multiplying the intensity with which electricity is employed in producing the resource aggregate, by the latter's intensity in overall output ($a_{ERj}a_{Rj}$). Derivation of these energy intensities for all six sectors is captured by equations (35)-(68).

The locational submodels for primary metals and chemicals are outlined in equations (69)-(86). They replace the missing zero profit conditions. Equations (69)-(77) describe how New York State's share of national output in the primary metals sector is determined. The ratio of primary factor cost in state j to that in the rest of the U.S. (the base region) is related to an index: fP_j via the functions (69)-(75). The logistics function in equation (76) utilizes these indices to determine New York's share of the national primary factor aggregate (CAGP/CAGPUS). Because CAGPUS is assumed to be determined exogenously, the magnitude of primary factor expenditures in the state is now known. Based on c_p, the unit cost of producing this aggregate, total output allocated to the state (P) can be found. A similar model for chemicals is described by equations (78)-(84). Since the number of states in the pooled data set is smaller (5 as opposed to 7 in the case of primary metals), the number of indices (fC_m) is smaller.

The remaining equations comprise the final demand conditions and accounting identities in the New York State model. Equation (87) generates state income (Y) as the sum of the returns to domestically owned primary factors. Since electricity prices vary by sector, each source of electricity revenue must be separately entered. (CD_e represents

Figure 2. The Empirical Model

(A) Intensities and Prices

(1)-(4): $[p_X \; p_A \; p_W \; p_O]' = \underset{(4\times9)}{(A)} [p_R \; p_K \; p_L \; p_C \; p_P \; p_X \; p_A \; p_W \; p_O]'$

(5)-(10): $p_{Rj} = p_{Rj}(p_{Ej}, p_F)$

(11)-(16): $c_j = c_j(p_{Rj}, p_K, p_L)$ $\qquad (j = C, P, X, A, W, O)$

(17)-(34): $a_{Rj} = \delta c_j / \delta p_{Rj}$

$a_{Kj} = \delta c_j / \delta p_K$

$a_{Lj} = \delta c_j / \delta p_L$

(35)-(68): $a_{ERj} = \delta p_{Rj} / \delta p_{Ej}$

$a_{FRj} = \delta p_{Rj} / \delta p_F$

$a_{Ej} = a_{ERj} a_{Rj}$

$a_{Fj} = a_{FRj} a_{Rj}$

(B) Locational Submodels

(69)-(75): $fP_k = AP_k + BP\ln(c_k/c_{ous})$ $\qquad k = 1, 2, \ldots, 7.$

(76): $CAGP = [\exp(fP_{NY})/(1 + \Sigma_k \exp(fP_k))]CAGPUS$

(77): $P = CAGP/c_P$

(78)-(84): $fC_m = AC_m + BC\ln(c_m/c_{ous})$ $\qquad m = 1, 2, \ldots, 5.$

(85): $CAGC = [\exp(fC_{NY})/(1 + \Sigma_m \exp(fC_m))]CAGCUS$

(86): $C = CAGC/c_c$

(C) Final Demand

(87) $Y = p_K K + p_L L + p_E CD_E + p_{EP} a_{EP} P + p_{EC} a_{EC} C + p_{EX} a_{EX} X + p_{EW} a_{EW} W$

$+ p_{EO} a_{EO} O + p_{EA} a_{EA} A - p_F a_{FE} (E - E_O)$

(88)-(94) $CD_i = DS_i Y/P_i$ $\qquad (i = E, F, P, C, X, W, A)$

(95) $Y = \Sigma p_i CD_i$

(D) Accounting

(96)-(105):

$$\begin{bmatrix} E \\ O \\ K \\ L \\ C \\ P \\ X \\ A \\ W \\ O \end{bmatrix} = \underset{(10\times6)}{(A)^*} \begin{bmatrix} C \\ P \\ X \\ A \\ W \\ O \end{bmatrix} + \begin{bmatrix} CD_E \\ CD_F \\ 0 \\ 0 \\ CD_C \\ CD_P \\ CD_X \\ CD_A \\ CD_W \\ CD_O \end{bmatrix} + \begin{bmatrix} 0 \\ NEF \\ 0 \\ 0 \\ NEC \\ NEP \\ NEX \\ 0 \\ 0 \\ 0 \end{bmatrix}$$

(Quantity Available) = (Intermediate Demand) + (Final Demand) + (Net Exports) the final demand for electricity.) The last term in the factor income expression indicates that, as electricity use in the state is changed from its initial equilibrium level (E_O), purchased fuel imports also change. (The coefficient a_{FE} indicates the amount of purchased fuels required to generate a unit of electricity.)

Equations (88)-(94) indicate that the final demand (including consumption, investment and government demands) for commodity i (CD_i) is assumed to remain a constant share of total income (DS_i). Since the demand shares are constrained to sum to one, the equation for one sector (O) has been omitted, and the budget constraint becomes equation (95). The final group of equations summarize the accounting conditions. NE_i is the net export of product i. With P_E and P_F determined exogenously, domestic availability of these factors is endogenous. In the case of purchased fuels it is assumed that all supplies are imported ($F = 0$, $NEF < 0$). Both electricity and purchased fuels are employed in intermediate as well as final uses. A* is a 10 x 6 matrix of factor intensities. The other point worthy of note is that the only commodities which are tradeable in the model are C, P and X (i.e., manufacturing output). The other sectors are forced to match state supply with state demands in equilibrium.

The relationship between equilibrium prices and intensities on the one hand, and production, consumption and net export levels on the other, depends on the degree to which state prices are determined exogenously (by the rest of the nation). Samuelson (1953) has demonstrated that there are three important cases for a competitive economy exhibiting constant returns to scale.

i) When the number of exogenous commodity prices equals the number of endogenous factor prices, equilibrium prices and intensities are independent of output levels.

ii) When the number of exogenous commodity prices exceeds the number of endogenous factor prices, specialization will occur, with some sectors' output dropping to zero.

iii) Only when there are more endogenous factor prices than exogenous commodity prices will factor intensities and price levels depend on final demand.

Since sectors C and P are not constrained by zero profit conditions, their exogenous commodity prices may be ignored in considering Samuelson's cases. This leaves two endogenous factor prices (P_K and P_L), and only one competitive sector with an exogenous commodity price (X). Thus case (iii) applies, and factor intensities in this model will depend on factor endowments and final demand. Note that if one additional price is fixed, only 68 endogenous variables remain in equations 1-68 (A), and Samuelson's Non-substitutability Theorem (1966) holds (case (i)).

IV. MODEL ESTIMATION AND CALIBRATION

Table 3 outlines expenditure shares for each of the six sectors of the economy. The intermediate input cost shares were obtained from a regionalized input-output table for New York State and are interpreted as fixed technological coefficients in this model.[9] At the bottom of the table, data on primary factor shares is provided. These indicate the cost share of each of the four primary factors of production in the total cost of the primary factor aggregate. The sectors are arranged from left to right according to electricity's share in the aggregate. Recall, however, that these sectors face different electricity prices (Table 2), and a comparison of relative cost shares will understate the differences in physical factor intensities. Despite paying a lower price, primary metals again stand out as being particularly intensive in the use of electricity, with agriculture and non-energy mining at the other extreme.

The initial impact of introducing (or eliminating) partial factor subsidies will be largely determined by the sign and magnitude of the partial elasticities of substitution among primary factors of production (Hertel, 1983c). Thus, it is desirable to estimate the primary factor cost functions using flexible forms which do not place rigid, a priori restrictions on these elasticities. This is particularly important for the subsidized sectors: primary metals, chemicals, and electricity extensive manufacturing, because this is where the largest relative price changes will occur in the policy simulations considered below. Fortunately, the Annual Survey of Manufactures provides a rich source of time series data for these sectors,[10] and transcendental logarithmic

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[9] Since a recent input-output table was not available for New York State, an algorithm developed by Boisvert and Bills (1976) for generating regional I-O tables was employed. Their approach involves imposing national production technology on the state economy at a very disaggregate level (4 digit SIC code sectors). The table is then aggregated to the desired degree, using state employment data, to arrive at the appropriate sectoral composition. The 1972 national I-O table was used, along with 1977 employment data from the U.S. Bureau of the Census' County Business Patterns.

[10] The Annual Survey of Manufactures data set includes observations on value-added and employment (quantity and cost). In addition, relatively detailed information on energy consumption is available over the period 1971-78. Data on the quantity and cost of energy consumed are provided for electricity, fuel oil, coal and natural gas. However, the electricity data is the only complete series, with the other three categories containing numerous gaps at the two-digit level. Thus, all of the latter inputs were aggregated into one category, purchased fuels, for which the time series was complete.

This cost and quantity information permitted construction of primary factor cost shares and average price series for inputs L, E, and F. Capital's cost share was then determined as a residual. The price of capital was constructed according to the Hall-Jorgenson (1967)

Table 3 Expenditure Shares

	Sectoral Cost Shares						Share of Final Demand
	P	C	X	W	O	A	
Intermediate Inputs:							
P	.2323	.0116	.0449	.0002	.0046	.0008	.000
C	.0200	.2318	.0229	.0027	.0008	.0341	.001
X	.0913	.0722	.3118	.0857	.0626	.1310	.272
W	.0742	.0818	.0894	.1099	.0941	.0562	.496
O	.0727	.0898	.0597	.1102	.1767	.0901	.210
A	.0648	.0202	.0126	.0042	.0020	.2054	.002
Primary Aggregate:	.4447	.4926	.4587	.6871	.6592	.4824	--
Totals	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	
Primary Factor Shares (in aggregate)	Translog Sectors (for 1977)			Cobb-Douglas Sectors			
	P	C	X	W	O	A	
E	.056	.016	.014	.013	.006	.004	.010
F	.082	.031	.013	.009	.012	.008	.009
K	.400	.721	.500	.332	.620	.556	--
L	.462	.232	.473	.646	.362	.432	--
Totals	1.000	1.000	1.000	1.000	1.000	1.000	1.000

cost functions could be estimated. Expenditure data for the remaining sectors (W, O, and A) are not readily available at the state level, and this data problem forced the use of simpler, Cobb-Douglas cost functions. Constant cost shares for the primary factor aggregate in these Cobb-Douglas sectors were obtained by combining information from the regionalized input-output table with labor cost data from County Business Patterns.

Translog Cost Functions

Figure 2 provides the translog cost structure for primary metals. These replace the conditions for unit costs and intensities (for $j = P$) written in general form in Figure 1. Equations (1) through (3) describe the first step of the firm's optimization exercise. At this point the cost minimizing mix of electricity and purchased fuels, comprising the energy aggregate (R), is selected. An analogous set of equations (4)-(7) describes cost minimization with respect to the (translog) primary factor aggregate cost function. Recall that the intensity with which electricity and purchased fuels are employed in the primary factor aggregate is equal to the intensity with which they are employed in R, multiplied by the intensity with which the energy aggregate is employed in the primary factor aggregate (equations 8 and 9). The cost structure for the other two manufacturing sectors (C and X) is identical to that in Figure 2.

The Cobb-Douglas sectors' cost structure may be derived by simply setting all of the second order terms in Figure 2 equal to zero. This forces cost shares to remain constant in the face of changes in relative prices, and the log of unit cost simply equals the weighted sum of the logs of individual prices and an intercept term. In addition, since the Cobb-Douglas functional form imposes separability among all inputs, the energy submodel is no longer necessary. Thus the cost structure in Figure 2, with all second order terms equal to zero, is equivalent to a single stage, Cobb-Douglas model with four inputs: K, L, E, and F.

It is important to point out that the sectoral models outlined here embody the maintained hypothesis of cost minimization in all sectors. In order to derive variable input-output coefficients (factor intensities), Shephard's Lemma must be invoked. While it is theoretically possible to test for cost minimization in the translog framework (e.g. Appelbaum, 1978), the conclusions will not be definitive given the limitations of the pooled data sets employed here. Thus, in this research effort, the hypothesis that all of the cost functions are well-behaved is maintained but not tested. Instead, the methodology involves estimating "well-behaved" translog cost functions.

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formula for the service price of capital. Effective corporate tax rates in individual states were estimated from information on federal and state corporate tax collections, as well as total U.S. corporate profits, following a procedure outlined by Field and Grebenstein (1980).

Figure 2 Translog Cost Structure for Primary Metals

$$\left.\begin{aligned}
&(1)\quad \ln p_R = G_0 + G_E \ln p_E + G_F \ln p_F + 0.5G_{EE}(\ln p_E)^2 \\
&\qquad\qquad + G_{EF}\ln p_E \ln p_F + 0.5G_{FF}(\ln p_F)^2 \\
&(2)\quad a_{ER} = (G_E + G_{EE}\ln p_E + G_{EF}\ln p_F)p_R/p_E \\
&(3)\quad a_{FR} = (G_F + G_{EF}\ln p_E + G_{FF}\ln p_F)p_R/p_F
\end{aligned}\right\}\ \text{Energy Resource Aggregate}$$

$$\left.\begin{aligned}
&(4)\quad \ln c_P = B_0 + B_L \ln p_L + B_K \ln p_K + B_R \ln p_R + 0.5[B_{LL}(\ln p_L)^2 \\
&\qquad\qquad + B_{KK}(\ln p_K)^2 + B_{RR}(\ln p_R)^2] + B_{LK}\ln p_L \ln p_K + B_{KR}\ln p_K \ln p_R \\
&(5)\quad a_{LP} = (B_L + B_{LL}\ln p_L + B_{LK}\ln p_K + B_{LR}\ln p_R)c_P/p_L \\
&(6)\quad a_{KP} = (B_K + B_{LK}\ln p_L + B_{KK}\ln p_K + B_{KR}\ln p_R)c_P/p_K \\
&(7)\quad a_{RP} = (B_R + B_{LR}\ln p_L + B_{KR}\ln p_K + B_{RR}\ln p_R)c_P/p_R \\
&(8)\quad a_{EP} = a_{ER}a_{RP} \\
&(9)\quad a_{FP} = a_{FR}a_{RP}
\end{aligned}\right\}\ \text{Primary Factor Aggregate}$$

A continuous cost function is well-behaved if it satisfies the following three conditions:

i) symmetry and linear homogeneity in prices,
ii) monotonicity, and
iii) concavity in input prices.

The first condition can be imposed when the translog cost function is estimated (Binswanger, 1974), while the second and the third conditions must (in general) be checked.[11] Monotonicity is satisfied if all estimated cost shares are non-negative. In the translog framework the concavity condition is most easily checked by working with the matrix of partial elasticities of substitution implied by the estimated coefficients. If this matrix is negative semi-definite, then so also is the matrix of second partial derivatives: $\{\delta^2 C/\delta p_i \delta p_j\}$, which in turn implies concavity of the cost function in input prices (Binswanger, 1974).

Data and estimation: There were two criteria for selecting the states to be included in these pooled data sets. State output in the relevant sector must be (a) relatively large, and (b) similar in composition to their counterpart sector in New York. On this basis data sets consisting of six states, in the case of chemicals, and eight states in the cases of primary metals and electricity extensive manufacturing were constructed.[12] Zero and first order terms in the translog cost functions are permitted to vary by state. Rearranging equations (2) and (3) from Figure 2 yields the two cost share equations for the energy

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[11] Lau (1974) has demonstrated that the Cholesky factorization of the Hessian matrix can be employed, in the estimation of flexible functional forms, such that the desired monotonicity and concavity restrictions are imposed on the data. He proposes a maximum likelihood estimator which reduces to a quadratic programming problem (p. 444).

[12] In the case of chemicals, the composition criterion involved looking for states with a similar organic/inorganic mix of chemical production. The net result was the selection of Illinois, Michigan, New Jersey and Pennsylvania, in addition to New York and the remainder of the United States. This provided a pooled data set with 48 observations. For primary metals, the combined criteria of importance and composition led to the selection of Alabama, Indiana, Kentucky, New York, Ohio, Tennessee, Texas and finally, the remainder of the U.S. All of the states in this group have substantial primary aluminum components in their primary metals sectors, while also producing ferrous metals. This yields 64 observations on cost shares and prices for sector P. Electricity extensive manufacturing is too diverse to enable the selection of states for pooling based on a single measure of composition. Instead, seven Middle Atlantic and North Central States which correspond to "old industrial states" were selected. This group includes: Indiana, Illinois, Michigan, New Jersey, New York, Ohio, Pennsylvania. When combined with the rest of the U.S. this yields eight cross-sectional units.

aggregate. Since these shares are restricted to sum to one, only the electricity share equation is employed in the estimating form of the model. Efficiency is enhanced by adding the unit cost function to the estimating form of the model. Imposing symmetry as well as linear homogeneity in prices and in output, and writing the model in terms of deviations from state means, results in the following estimating equations:

$$S_{Eij} = (G_{ENY} + G_{Ej}D_j) + G_{EE}\ \ln(p_{Eij}/p_{Fij}) + u_{ij}$$

$$\begin{aligned} DEV(\ln p_{Rij}) = {} & (G_{ENY} + G_{Ej}D_j)DEV[\ln(p_{Eij}/p_{Fij})] + G_{EE}DEV[0.5(\ln p_{Eij})^2 \\ & - \ln p_{Eij}\ln p_{Fij} + 0.5(\ln p_{Fij})^2] + v_{ij} \end{aligned}$$

where DEV[ ] indicates measurement in deviations from state means, i = years: 1971-1978, j = states, u, v are error terms, and D_j are state dummy variables.

New York's intercept (G_{ENY}) provides the base value, with intercept terms for state j equal to ($G_{ENY} + G_{Ej}$). Note that these state specific intercepts are constrained to be equal across equations.[13] Imposition of this constraint is one reason for estimating the equations simultaneously. In addition, since the terms u_{ij} and v_{ij} are assumed to be the result of errors in cost minimization, they are likely to be contemporaneously correlated within any given state. Thus Zellner's seemingly unrelated regression technique is employed. The iterative version of this technique is equivalent to maximum likelihood estimation, and thus insures uniqueness of the estimates regardless of the share equation that is dropped (Kmenta and Gilbert, 1968).

The next level of cost minimization involves capital and labor inputs, as well as the energy resource aggregate. The absence of observations on output restricts estimation to share equations. In this instance, with three inputs, two share equations are estimated simultaneously. Estimating equations are provided below. Note that the labor share equation has been dropped and the equations have been normalized on the price of labor.

$$DEV[S_{Kij}] = B_{KK}DEV[\ln(p_{Kij}/p_{Lij})] + B_{KR}DEV[\ln(p_{Rij}/p_{Lij})] + u_{Kij}$$

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[13]Alternatively, one may postulate that state effects are stochastic and thus are subsumed in the error term. Error components estimators takes this interregional variation into account, thus increasing efficiency (Maddala, 1971). However, the latter models must assume that the cross-sectional effects are truly random and thus not correlated with the exogenous variables. Furthermore, Swamy and Arora (1972) find that, when the number of cross sections is small, the error components estimator may not be more efficient than estimating state specific intercepts.

$$DEV[S_{Rij}] = B_{KR}DEV[\ln(p_{Kij}/p_{Lij})] + B_{RR}DEV[\ln(p_{Rij}/p_{Lij})] + u_{Rij}$$

Once again, i = years, j = states, and u_{Kij} and u_{Rij} are error terms. Cross-section effects are implicitly included because the logarithmic price ratios are in terms of deviations from state means (DEV[ ]).

State intercepts may be computed directly from the relevant state's mean logarithm of prices and shares, along with the estimated slope coefficients. For example, the intercept for New York's capital share equation is provided by the following equation:

$$B_{KNY} = \overline{S_{KNY}} - B_{KK}\overline{\ln(p_{KNY}/p_{LNY})} - B_{KR}\overline{\ln(p_{RNY}/p_{LNY})}$$

Note that the intercepts will vary, depending on the units in which prices are defined. They are thus "scale-dependent". For this reason the econometric estimates of these intercepts are rescaled as part of the model's calibration.

The iterative Zellner estimates of the slope coefficients for primary metals, chemicals and electricity extensive manufacturing are provided in Tables 4, 5, and 6, respectively. The t-statistics are provided in parentheses below each estimate. Note that these t-statistics can be used to test the departure of the production structures from a Cobb-Douglas form. In the case of the latter, when all of these second order coefficients would be zero (i.e., relative price changes do not affect cost shares). Derived demand elasticities implied by the estimated coefficients are also provided in these tables, along with the associated standard errors.[14]

Consider first the energy submodel for primary metals. The estimate for G_{EE} and the associated demand elasticities are provided at the top of Table 4. The large t-statistic (14.67) associated with G_{EE} indicates that a constant cost share (Cobb-Douglas) aggregation function is not appropriate. The implication of the low demand elasticities is that there is little room for changing the composition of the energy aggregate employed in the primary metals sector. This result conforms with expectations for the pooled data set selected, in which primary aluminum consumes a large share of the electricity employed in this sector. The process of aluminum reduction has been uniquely tied to electricity as a source of energy, thus implying that the substitutability between electricity and purchased fuels is very limited.

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[14]These derived demand elasticities (E_{ij}'s) are simple, linear functions of the estimated parameters for given values of the shares:

$E_{ij} = (B_{ij}/S_i) + S_j$ for all $i \neq j$.
$E_{ii} = (B_{ii}/S_i) + S_i - 1$.

Thus standard errors may be attached to the elasticities as follows:

$SE(E_{ij}) = SE(B_{ij})/S_i$ and $SE(E_{ij}) = SE(TS_{ii})/S_i$.

Table 4 Primary Metals Cost Function

Energy Submodel

	Estimated Coefficient (t statistic in parentheses)
	Electricity
E	0.1860
	(14.67)

	Derived Demand Elasticities (1977) (standard errors in parentheses)*	
	Electricity	Purchased Fuels
E	-0.13	0.13
	(0.03)	
F	0.09	-0.09

	R^2	$\bar{R}^2$
Unit cost function	0.990	0.988
Electricity share equation	0.875	0.857

Primary Factor Aggregate

	Estimated Coefficients (t statistic in parentheses)	
	Capital	Energy
K	0.0098	-0.0108
	(0.829)	(-1.688)
R		0.09787
		(9.995)

	Derived Demand Elasticities (1977) (standard errors in parentheses)*		
	Capital	Energy	Labor
K	-0.58	0.11	0.47
	(0.03)	(0.02)	
R	0.32	-0.15	-0.17
	(0.05)	(0.07)	
L	0.40	-0.05	-0.35

	R^2	$\bar{R}^2$
Energy share equation	0.807	0.804
Capital share equation	0.405	0.396

* Elasticities involving purchased fuels, and labor, are derived from the homogeneity restriction.

Iterative Zellner estimates for the primary factor aggregate in sector P are provided at the bottom of Table 4. The R^2 statistics indicate a rather poor fit for the capital share equation. This may well be due to the fact that capital's cost share has been derived as a residual. Furthermore, idle capacity has been a chronic problem in the primary metals sector in recent years, and this is not considered in the derivation of the service price of capital. The cross-demand elasticities for which standard errors may be easily computed are all substantially different from zero. They indicate that labor and energy are complementary inputs in this sector. Thus, a rise in the price of the energy aggregate (holding output and other prices constant) causes a drop in employment. Finally, this primary factor cost function is not concave in input prices throughout the sample period. However, it is well-behaved for the 1977 and 1978 New York State observations.[15] This is very important because 1977 is the benchmark year for the model.

Coefficients resulting from iterative Zellner estimation of the chemical sector's two-stage cost function are presented, along with the implied demand elasticities, in Table 5. The estimate of the second order coefficient in the energy submodel appears to be substantially different from zero, with a t-value of 23.67. The primary factor aggregate for chemicals was estimated using energy and capital share

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[15]Out of a total of 64 sample points in the pooled data set, the cost function for sector P's primary factor aggregate was quasi-concave (one positive characteristic root) for 24 of the observations. Almost all of these ill-behaved points fell in the first half of the sample period (1971-1974). The explanation for this pattern of quasi-concavity is readily explicable upon consideration of the tremendous change in the cost share of energy in sector P's primary factor aggregate (S_R) over this period. This share doubles in many of the states in the pooled data set. However, in New York State it starts out at a relatively low level (9%), and its increase is more modest (to 13%). Since the Allen partial elasticities of substitution are inversely related to this factor share, these elasticities also vary substantially over the sample period. The formula for the own partial elasticity of substitution for the energy aggregate is:

$$\sigma_{RR} = (B_{RR}-S_R)/S_R^2 + 1.$$

While S_R varies over the sample period, the estimated coefficient (B_{RR}) is constant and positive for sector P. Thus, a very small value for S_R can lead to a positive own price elasticity which in turn disrupts the conditions for concavity in input prices.

The policy experiments carried out below involve increasing the price of energy (electricity) paid by sector P. Given the relatively inelastic demand for this input in primary metals production, this means that the cost share of energy will increase from their benchmark (1977) value, keeping the outcome in the well-behaved portion of the cost function. However, the fact remains that the cost function for sector P is only locally well-behaved.

Table 5 Chemicals Sector Cost Function

Energy Submodel

Estimated Coefficient (t statistic in parentheses)

	Electricity
E	-0.0973
	(-23.67)

Derived Demand Elasticities (1977) (standard errors in parentheses)*

	Electricity	Purchased Fuels
E	-0.95	0.95
	(0.01)	
F	0.49	-0.49

	R^2	$\bar{R}^2$
Unit cost function	0.960	0.954
Electricity share equation	0.592	0.532

Primary Factor Aggregate

Estimated Coefficients (t statistics in parentheses)

	Capital	Energy
K	-0.0010	-0.0031
	(-0.23)	(-1.76)
R		0.0334
		(0.437)

Derived Demand Elasticities (1977) (standard errors in parentheses)*

	Capital	Energy	Labor
K	-0.29	0.04	0.25
	(0.006)	(0.002)	
R	0.67	-0.24	-0.43
	(0.037)	(0.075)	
L	0.75	-0.08	-0.67

	R^2	$\bar{R}^2$
Energy share equation	0.893	0.890
Capital share equation	0.796	0.791

* Elasticities involving purchased fuels, and labor, are derived from the homogeneity restriction.

equations, with a much better fit for the latter than was the case for sector P. Once again, labor and energy are complementary inputs. Also worthy of note is the fact that the estimated own price elasticity for energy is substantially greater for chemicals than it was for primary metals. For New York State's cost shares, this cost function is well-behaved over the period 1974-78.[16]

The last of the sectors for which a two-stage cost function was estimated is the electricity extensive manufacturing sector (X). Ordinary least squares estimation of the second order coefficient in the unit cost function and the share equation separately yielded roughly the same value (0.09). However, when estimated as a system, with cross equation restrictions, this second order coefficient doubled to 0.18. The larger estimate resulted in a positive own price effect for electricity in the energy submodel, and was thus rejected in favor of the single equation estimate taken from the electricity share equation (see Table 6).[17] Estimation of the translog primary factor aggregate in sector X is identical to that in the previous two sectors. The two share equations exhibit relatively high R^2 values, and labor is once again complementary to energy, while capital-energy and labor-capital relationships are characterized as substitutes. This cost function is well-behaved over 57 of the 64 data points including 1974-78 for New York State.

Comparison with estimates from the literature: Over the last ten years, a great deal of research has been directed towards the estimation of the elasticities of substitution between energy, and labor or capital inputs in the manufacturing sector. Turning first to the elasticity of substitution between capital and energy (e_{KR}), there are two distinct groups of estimates. The first group of studies (Berndt and Wood, 1975; Berndt and Jorgenson, 1973; Norsworthy and Harper, 1979) find that capital and energy are complementary inputs. A second group (Gregory and Griffin, 1976; Halvorsen and Ford, 1981; Pindyck, 1977) finds that

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[16]Initial estimates of this cost function, using five states and the remainder of the U.S. in a pooled data set over the 1971-78 period, violated the restrictions implied by cost minimization. When evaluated over a substantial portion of the data set (including all observations for New York State) it exhibited a positive own price effect for electricity. Upon closer examination of the pooled data set, it was found that there existed a rather large difference in the composition (organic/inorganic mix) of the chemical sector in the five individual states, as opposed to the rest of the U.S. When observations for the rest of the U.S. were dropped, the cost function was found to be well-behaved over 28 of the 40 sample points. (Early years in the data set are subject to the same small-share problem identified in the case of the primary metals cost function.) It is the latter group of estimated coefficients which were utilized in the model, and they are summarized in Table 5.

[17]The large difference between the single equation and system estimates may be explained by the fact that the latter constrains state-specific intercepts in the two equations to be equal.

Table 6 Electricity Extensive Manufacturing Cost Function

Energy Submodel

Estimated Coefficient (t statistic in parentheses)

	Electricity
E	0.0929
	(6.04)

Derived Demand Elasticities (1977) (standard errors in parentheses)*

	Electricity	Purchased Fuels
E	-0.29	0.29
	(0.03)	
F	0.34	-0.34

	R^2	$\bar{R}^2$
Electricity share equation	0.744	0.707

Primary Factor Aggregate

Estimated Coefficients (t statistics in parentheses)

	Capital	Energy
K	0.0605	-0.003
	(0.11)	(-3.3)
R		0.021
		(14.62)

Derived Demand Elasticities (1977) (standard errors in parentheses)*

	Capital	Energy	Labor
K	-0.490	0.020	0.470
	(0.009)	(0.002)	
R	0.385	-0.166	-0.219
	(0.034)	(0.053)	
L	0.495	-0.012	-0.483

	R^2	$\bar{R}^2$
Energy share equation	0.906	0.904
Capital share equation	0.810	0.807

* Elasticities involving purchased fuels, and labor, are derived from the homogeneity restriction.

they are substitutes in production, while another study (Fuss, 1977) finds the elasticity of substitution between capital and energy (e_{KR}) to be close to zero. These research efforts differ along a number of dimensions including: country of study, nature of the data (time series vs. cross section), production structure (some include materials, while others do not), and the definition of capital. Several studies have attempted to reconcile the divergent estimates on the basis of these differences.

Berndt and Wood (1979) have stressed the role of the materials input, noting that as long as firms can substitute materials for the primary factor aggregate, estimates of the gross elasticity (holding the level of the aggregate constant), will overstate the net elasticity (holding total output constant). By employing some plausible values for key parameters, the authors conclude that the gross substitutability result of Griffin and Gregory is consistent with the hypothesis of net capital-energy complementarity. In the New York State model it is assumed that materials do not substitute for the primary factor aggregate, so that net and gross elasticities are constrained to be equal. Thus, if such substitution does in fact exist, the fixed coefficient structure biases the estimate of the net elasticity in favor of increased substitutability.

The definition of capital is also an important factor in explaining diverse estimates of e_{KR}. Field and Grebenstein (1980) point out that there are at least two important components to capital: physical stock and working capital. Furthermore, it is the use of data on capital stock which leads to the Berndt, et al. estimate of $e_{KR} < 0$, whereas the studies concluding that K and R are substitutes have tended to work with the value of capital services derived as a residual. The latter procedure combines physical and working capital. By separating the two types of capital, Field and Grebenstein are able to show that, while services from the physical capital stock and energy are complements, energy and working capital are substitutes in production. Since the data employed in this analysis treats the two forms of capital together, it is perhaps not surprising that the implied capital-energy substitutability in manufacturing coincides with the conclusion of those studies using a similar definition of K.

It has also been pointed out that there may be a fundamental difference in the short run e_{KR} as opposed to the long run elasticity of substitution between capital and the energy resource. Griffin and Gregory reconcile their result for cross-section data ($e_{KR} > 0$) with the time series conclusions ($e_{KR} < 0$) by arguing that they are capturing long-run effects. They maintain that, in the short run, an increase in the price of energy renders a portion of the capital stock obsolete, hence reducing capacity utilization. However, in a recent study of the dynamic demand for inputs in U.S. manufacturing (Denny, et al., 1979), the authors find that physical capital and energy are long-run complements in all but a few sectors. Particularly interesting is that two of the exceptions are primary metals ($e_{KR} = 2.43$) and chemicals ($e_{KR} \cong 0$) (p. 37).

Another parameter of great importance to the general equilibrium interactions in the New York State model is the elasticity of substitution between labor and the energy aggregate (e_{LR}). Turning again to the existing literature, there appears to be general agreement among static models of national manufacturing activity that labor and energy are substitutes. However, the results from recent dynamic models are mixed (e.g., Denny, et al., 1979). The interesting feature of the latter models is that the qualitative nature of input substitution may change between the short and the long run. For example, the authors find that labor and energy are short-run substitutes and long-run complements in the primary metals sector.

Regional differences in the technology and composition of manufacturing activity can also play a significant role in explaining divergent findings. For example, the complementary relationships found in this study conform with an earlier study (Considine, 1981) which utilized pooled data for Middle Atlantic and North Central States to estimate cost share equations for the aggregated manufacturing sector. In addition, both of these investigations conclude that $e_{KR} > 0$. Finally, it should be noted that labor and energy resources are substitutes in the non-manufacturing sectors because of the Cobb-Douglas form which is assumed.

Locational Models: Estimation of the locational submodels for sectors C and P is based upon the primary factor unit cost functions provided in the previous section. The model utilizes the logistics function (Berkson, 1941) to approximate each state's share in national output. Consider first, the locational submodel for sector P provided in Table 7. On the left hand side is the log of the ratio of "output" allocated to state i to that allocated to the rest of the U.S. The explanatory variable is the log of the ratio of primary factor costs. The negative coefficient indicates that as production in i becomes more costly, it will be shifted out of the state. This coefficient may be translated into the BP associated with equations (69)-(75) in Figure 2 by adding one. Thus, with a ratio of cost shares on the left hand side, the coefficient: BP = 0.151 applies. The high R^2 associated with the primary metals locational model indicates an excellent "fit" of the estimated model to the pooled data, when the intercept term is permitted to vary across states. The intercept (-2.556) is that for New York (AP_{NY} in Figure 2). The remaining intercepts, constructed by adding the relevant dummy coefficient to the New York intercept, are not shown here.

The locational submodel for the chemical sector is given at the bottom of Table 6. The fact that (BC-1) is almost equal to -1 indicates that the allocation of primary factor cost shares to the states in the pooled data set is almost invariant to relative price changes because relative quantities change by an almost equal percentage. Once again, the fit of this static model is quite good.[18]

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[18]It seemed quite possible that the desired allocation of national output expenditures) to individual states might not be achieved in the course single year, particularly if excess capacity did not exist.

Table 7 Locational Submodels for Chemicals and Primary Metals (t statistics in parentheses)

Primary Metals

$$\ln(Q_{it}/Q_{oust}) = \underset{(-72.4)}{-2.556} - \underset{(-14.334)}{0.849} \ln(c_{it}/c_{oust}) + \text{estimated state effects.}$$

for $i = 1, \ldots, 7.$

$t = 1971\text{-}78$

$R^2 = 0.992$

$\bar{R}^2 = 0.991$

Chemicals

$$\ln(Q_{it}/Q_{oust}) = \underset{(-11.8)}{-2.495} - \underset{(-5.1)}{0.969} \ln(c_{it}/c_{oust}) + \text{estimated state effects.}$$

for $i = 1, \ldots, 5.$

$t = 1971\text{-}78$

$R^2 = 0.965$

$\bar{R}^2 = 0.959$

Model Calibration

Methods for calibrating computable general equilibrium models to benchmark data sets have been well documented (e.g., Mansur and Whalley, 1981; St.-Hilaire and Whalley, 1982). They amount to translating observed "equilibrium" values into quantities by picking initial prices which are all equal to one. This permits scaling parameters in the production (cost) functions to be derived through sectoral zero profit conditions. In the case of Cobb-Douglas technology, benchmark cost shares become the exponents, while use of CES technology requires that the constant elasticity of substitution be provided exogenously. The translog cost functions employed for manufacturing sectors in the New York State model present a somewhat more complex problem, because both zero- and first-order terms are scale dependent. The calibration procedure adopted is to utilize equilibrium cost shares to pick the first-order terms (these are intercepts in the translog cost share equations), while using zero profit conditions to derive the zero-order term.[19]

Because interstate flows of commodities and factors of production are difficult to estimate, there is a serious gap in the benchmark data set. Where such data is available it is common to treat domestic and imported items as distinct products in order to replicate an observed equilibrium. While this may be plausible for national models, it is far less reasonable at the state level. In order to circumvent these problems, the prices of tradeable items are assumed to be determined in the national marketplace (exogenously), with net exports being determined as a residual. This means that initial equilibrium output levels are not constrained to equal observed levels. However, in order to assure a reasonable initial solution, payments to labor and capital are constrained to equal their observed values in initial equilibrium.

A final aspect of the model's calibration is necessitated by the locational submodels for primary metals and chemicals. Recall that output is allocated to the state based on the production costs in New York, relative to those in the rest of the nation. In order to calibrate the model, these ratios are assumed to equal their observed (1977) values in initial equilibrium.

(This might be true for chemicals, but not for primary metals.) Thus, a geometric lag structure was added to the model. In the case of the chemical sector the lag structure was insignificantly different from zero, and in the case of primary metals the coefficient on the lagged endogenous variable was slightly negative. Based on these results, the static versions of these locational models were deemed most appropriate.

[19]The chemicals and primary metals sectors are non-competitive and thus may exhibit profits and losses. However, for purposes of calibration it is assumed that, in initial equilibrium, they are not earning profits. (This condition is relaxed for the policy simulations.)

V. PARTIAL AND GENERAL EQUILIBRIUM ANALYSES: EXPLORING THE STRUCTURE OF THE MODEL

Before proceeding to conduct policy simulations with this model, it is useful to become acquainted with how it works -- that is, what happens when, for example, manufacturing electricity prices increase? As was pointed out in Section II, general equilibrium effects of this removal of a partial factor subsidy may be very important. However, we will begin with a partial equilibrium analysis, insulating the subsidized sectors from any feedback effects. This may be considered a first approximation, which does not require the full model. The next step will be to permit non-tradeable factor and commodity prices to vary, thereby initiating general equilibrium interactions. Comparison of the two outcomes should serve a dual purpose. Not only does it facilitate understanding of the model's operation, it also sheds some light on the question of when one can expect partial equilibrium analyses to provide a good approximation to economy-wide outcomes.

Partial Equilibrium Results in the New York Model

The first column in Table 8 provides initial equilibrium values for the New York State model in 1977. Removal of the subsidies implicit in the current rate structure results in immediate electricity price increases to sectors P, C, and M of 217%, 111% and 27%, respectively. Because these are all tradeable sectors, commodity prices are fixed exogenously and general equilibrium interactions are initiated in the factor markets. In particular, since the prices of (unsubsidized) electricity and purchased fuels are also fixed in this short run model, it is the markets for capital and labor which transmit the shock to non-manufacturing sectors. Thus, holding P_K and P_L constant yields sectors' P, C, and X partial equilibrium responses to removal of the subsidies. These are provided in the second column of the table.

Turning first to primary metals, electricity intensity (a_{EP}) drops by only 24%, despite a 217% price hike. Purchased fuels substitute marginally for electricity in this sector, but a drop in the intensity with which the energy aggregate is employed results in a_{FP} remaining almost unchanged. There is a slight drop (-1.95%) of the labor intensity in sector P, due to the fact that labor and electricity are complementary inputs. It appears that most of the electricity savings in response to the drastic price increase occurs as a result of capital-energy substitution. This is evidenced by an 8.6% increase in the intensity of capital services in the primary metals sector. The net result of this sector's cost minimizing response to rate equalization is that the unit cost of the primary factor aggregate (c_p) rises by more than 10%. This translates (through the oligopolistic, locational model) into an 8.1% drop in primary metals output allocated to the state.

Consideration of the value of a_{EC} in column (2) of Table 4 shows that the decline in electricity intensity in the chemical industry is almost double that in primary metals, despite the fact that the percentage price increase in the chemicals sector is only one-half as large. The main reason for this is increased use of purchased fuels.

Table 8. Partial and General Equilibrium Simulations

Endogenous Variables	Initial Equilibrium Values (1977) (1)	Effect of Removing Electricity Price Differential (% change from initial equilibrium) Partial Equilibrium (2)	General Equilibrium (3)
Factor Prices			
p_K	1.0	--	-0.14
p_L	1.0	--	-0.42
Intensities			
a_{EP}	0.1245	-24.38	-24.40
a_{FP}	0.0365	+0.14	+0.11
a_{LP}	0.2055	-1.95	-1.83
a_{KP}	0.1779	+8.60	+8.51
a_{EC}	0.0263	-56.20	-56.18
a_{FC}	0.0153	+30.43	+30.48
a_{LC}	0.1143	-1.84	-1.68
a_{KC}	0.3552	+1.04	+1.01
a_{EX}	0.0128	-9.05	-9.36
a_{FX}	0.0060	+5.10	+5.09
a_{LX}	0.2170	-0.14	+0.10
a_{KX}	0.2294	+0.26	+0.15
Primary Factor Unit Costs:			
c_P	0.4447	+10.57	+10.12
c_C	0.4926	+1.16	+0.96
c_X	0.4587	+0.35	+0.09
Output Levels:			
P	4.5690	-8.10	-7.92
C	8.4880	-1.11	-0.93
X	74.0010	--	-0.02
Electricity Demand:			
E	3.8790	--	-10.06

As a result, unit cost (c_C) increases by only 1.16%, and production allocated to the state decreases by slightly more than one percent. The electricity extensive sector's response to rate equalization is similar to that for chemicals, only less drastic, since the price of electricity to X increases by only 27%. As was the case for primary metals, labor is complementary with electricity in sectors C and M, causing a_{LC} and a_{LX} to drop. Output in this competitive sector cannot be determined in the absence of the reminder of the model, but we would expect a slight drop.

General Equilibrium

As was shown in Section II, by permitting the prices of other factors (capital and labor) to vary in response to the factor substitution in sectors X, P, and C, general equilibrium interactions are initiated. Qualitative results developed elsewhere (Hertel, 1983b) indicate that there are two effects operating on the economy's wage-rental ratio, when a partial factor subsidy on the energy resource input is applied (or removed). These are: (1) a "relative substitutability effect", and (2) a "composition effect". The first arises when capital and labor substitute differentially for the energy aggregate (i.e., $\sigma_{KR} \neq \sigma_{LR}$). But the non-manufacturing sectors are modelled with Cobb-Douglas cost functions. Thus, capital and labor are constrained to substitute equally well for R ($\sigma_{KR} = \sigma_{LR} = 1$), and these sectors may be temporarily ignored. However, in the manufacturing sectors, capital substitutes for energy while labor is a complementary input ($\sigma_{KR} > \sigma_{LR}$). Thus, when the electricity subsidies are removed, the relative substitutability effect is expected to exert downward pressure on the wage-rental ratio. Labor is released from manufacturing, while capital is absorbed in an effort to conserve more costly electricity.

The composition effect is driven by differences in capital-labor ratios in the subsidized and unsubsidized sectors. In initial equilibrium: $K_C/L_C = 3.11$, $K_X/L_X = 1.06$, $K_P/L_P = 0.87$, yielding an average capital/labor ratio for all manufacturing of 1.12. This compares to an average for the remainder of the economy of 0.80. Thus, it can be asserted that the electricity subsidies serve to promote relatively capital intensive sectors. This means that elimination of the subsidies will be expected to increase the wage-rental ratio. The price of labor relative to capital will be bid up by the expansion of the labor intensive, non-manufacturing sectors. The direction in which P_L/P_K changes, will depend on whether relative substitutability or composition effects dominate. Referring to column (3) of Table 8, it appears that the former effect is the stronger of the two, as wages drop relative to the rental rate on capital.

While the change in P_L/P_K has been explained, there remains a question regarding the movement of these endogenous factor prices relative to exogenously dictated prices in the model. To address this issue, turn to the oligopolistic, locational models for sectors C and P. As unit production costs rise, New York's share in national output declines. The same is true for the competitive, tradeable sector X, which experiences a drop in exports. This means that pressure on the fixed factors of production diminishes and the prices of capital and labor are expected to decline, relative to the national price level.

Lower prices for capital and labor serve to alter the partial equilibrium intensities, reducing the unit cost of production in every sector. These general equilibrium outcomes are provided in the third column of Table 8. Close examination of the differences between partial and general equilibrium predictions indicates that the former are a very close approximation of the latter. Of course, there are endogenous variables of interest which are only available when the complete model is solved. In particular, rate equalization has a substantial effect on the use of electricity, with E dropping by 10%.

Under what conditions might the quality of this approximation deteriorate? That is, when might one expect feedback effects on the manufacturing sectors to be significant? There are two restrictions on the New York State model presented here which serve to limit these general equilibrum effects. The first is the assumption of a perfectly elastic supply of energy inputs. This serves to insulate the economy from changes in p_R resulting from energy conservation, as the electricity subsidies are eliminated.

A second restriction which limits the magnitude of the general equilibrium interactions is assumption that the prices for manufacturing output are fixed exogenously. This is based on the fact that these are commodities which are traded in relatively large, national (and international) markets. Thus elimination of the factor subsidies does not affect the price of output in the subsidized sectors. This serves to limit the change in composition of the New York State economy, resulting from elimination of the partial factor subsidies on electricity.

VI. POLICY ANALYSIS

Three departures from the current pattern of electricity subsidies are considered. The first two policies examine alternative, equal cost subsidies, while the final one considers the implications of eliminating the manufacturing subsidies altogether. Before discussing these simulation results, it is important to clarify the opportunity cost concepts employed in this section. From a supply perspective, it makes sense to use the marginal cost of generating and delivering an additional unit of electricity as the base from which departures (subsidies or taxes) are measured. Since the model treats capacity in the electric utility sector as exogenous, the inclination might be to approximate marginal cost with the fuel costs required by marginal (oil-fired) generation facilities. However, short-run marginal cost pricing can severely distort the utilities' longer-run, capacity planning. Thus, many studies have focused on the long-run marginal cost of power from a new (e.g., coal-fired) plant (Considine, 1981; Smith, 1982). Unfortunately, estimates of this key figure vary widely. In addition, since the model developed here treats electricity as a primary factor of production (taking generating capacity as given) it is somewhat confusing to introduce a long-run marginal cost concept.

Instead of using the supply-oriented opportunity cost concept relevant for an intermediate factor of production, a demand-based approach will be used. The opportunity cost of the publicly controlled hydropower resource will be defined in terms of the price at which it could be sold to the non-subsidized sectors. Thus, the electricity subsidies to sectors P, C, and X are measured as the difference between the price actually paid and the price which would have been received for the electricity had it been sold to the residential and commercial sector. As such, the policy analysis focuses on the impact of electricity price differentials.

There remains the question of how to adjust these sectoral price differences for the differential cost of transmitting and distributing electricity to residential and commercial customers on the one hand, and manufacturing customers on the other. The differential costs of electricity transmission and distribution to these two classes of customers are reflected in the adjusted electric rates which were provided in Table 2. They indicate effective subsidies amounting to 0.8 cents/kwh in the case of electricity extensive manufacturing, 2 cents/kwh for the chemicals sector and 2.6 cents/kwh in the case of primary metals. The total value of electricity subsidies to each of the manufacturing sectors depends on whether observed or equilibrium quantities are used. Actual electricity consumption in 1977, in each of these sectors, differs somewhat from the equilibrium values predicted by the model (calibrated for 1977). The primary metals sector received the largest subsidy in 1977: $226 million ($251 million predicted by the model). This is followed by electricity extensive manufacturing, which received $153 million ($126 million predicted by the model) and the chemicals sector with $60 million ($74 million in equilibrium). Thus, total manufacturing subsidies in 1977 amounted to $439 million ($451 million predicted by the model). In the discussion of alternative subsidy schemes below, it is the cost of the electricity subsidy in equilibrium which is alternatively applied to labor costs, and then to production costs.

Equal Cost Labor Subsidies

Perhaps the most striking feature of the PASNY proposal for reallocation of hydropower, which was mentioned in the introduction, is the fact that it leaves untouched almost 60% of the current allocations -- namely that hydropower going to industry. The reasoning behind this feature of the proposal is concisely stated in the Chairman's executive summary:

> Upstate New York would benefit [from the proposal] by retaining cheap power so critical to maintaining an estimated 100,000 jobs. The price that industry pays for this Authority power would remain the lowest in the United States. Also, the expansion power which is not protected by statute or contract would be retained for industrial use at similarly favorable rates [Dyson (1981), p. ii].

Given the overwhelming interest in keeping jobs in the state, it is interesting to consider whether or not there are alternative, more effective means of promoting employment. Common sense suggests that the best way to encourage the hiring of additional labor is to lower the effective wage rate facing firms.[20] In the context of the problem at hand, this intervention is modelled as a set of labor subsidies which are equal in cost to the existing electricity subsidies for each sector. Thus, instead of receiving $251 million in electricity rate reductions, the primary metals sector experiences a reduction in unit labor costs which (in the new equilibrium) has a total value of $251 million. The same policy is used for sectors X and C which receive reductions of $126 million and $74 million, respectively. This means that, under the labor subsidy scenario, all sectors are forced to pay the same price for electricity, net of transmission and distribution cost differentials.

In order to solve the model, with the equal cost subsidies in place, it is necessary to fix the price of labor exogenously. This provides an upper bound on the absolute change in state employment. It is also consistent with the assumption that the supply of labor is perfectly elastic (for small changes in demand such as those resulting here). The latter assumption may be justified if there exists a sufficient pool of unemployed (or underemployed) residents of the state, or if there is substantial interstate mobility of the labor force. Non-employment related data are not reported in Table 9 for the labor subsidy scenario because they are not strictly comparable to the other policy interventions as a result of fixing the wage rate exogenously.

Replacing the electricity subsidy with a labor subsidy reduces the wage rates facing sectors P, C, and X by 24%, 7%, and 1%, respectively.

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[20]This result is formally supported by theoretical work on the problem of optimal intervention (Bhagwatti, 1971).

Table 9. Impact of Alternative Policies (% change from initial equilibrium: 1977)

Target Variables	Equal-Cost Subsidies: Labor Subsidy (fixing P_L)**	Equal-Cost Subsidies: Production Subsidy	No Subsidies
Sectoral Output			
P	--	+1.38%	-7.92%
C	--	+0.49%	-0.93%
Employment (upper bound - fixing P_L)			
L	+0.35%	-0.47%	-0.74%
(change in jobs)*	(+24,600)	(-20,400)	(-51,000)
Relative Factor Returns			
P_L/P_K	--	-0.36%	-0.28%
Real Income			
Y	--	-0.05%	+0.16%
(change in mill. $)	--	(-71)	(+223)
Electricity Demand			
E	--	-9.00%	-10.06%

* Change in Sectoral Employment

Primary metals	+ 8,500	- 500	- 8,600
Chemicals	+ 3,400	- 1,100	- 2,600
Other manufacturing	- 3,600	- 7,000	-13,600
Wholesale/retail	+12,600	- 9,100	-18,100
Ag. and mining	0	0	- 900
Other	+ 3,700	- 2,700	- 7,200
	+24,600	-20,400	-51,000

** Non-employment values are not strictly comparable.

In the new equilibrium, which results in a 0.35% increase in state employment (Table 9), translates[21] into approximately 24,600 additional jobs. Most of this increase comes in primary metals (8,500 jobs) and the wholesale/retail sector (12,600 jobs). Employment in the former increases due to an increase in the intensity with which labor is employed (output actually drops). This is the result of the labor subsidy in that sector. Employment in the wholesale/retail sector increases as a result of increased output at an unchanged labor intensity. Employment in the chemicals sector increases by 3,400 jobs for the same reason as primary metals, while employment in sector X actually drops by 3,600. The latter occurs, despite the subsidy on labor, because the drop in output outweighs the marginal increase in the labor intensity of electricity extensive manufacturing.

Equal Cost Production Subsidies

Next, consider the effect of replacing each sector's electricity subsidy with a production subsidy of equal cost. Using the initial equilibrium (with electricity subsidies in place) as a baseline, the second column of Table 9 captures the effect of the production subsidy scenario on various target variables. Output in both oligopolistic sectors increases, but real[22] income drops. In evaluating this outcome, it is useful to draw on Miezkowski's (1966) results which are derived in the context of a perfectly competitive 2 x 2 model.[23] He demonstrated that, while production subsidies dominate factor subsidies as a mechanism for achieving a given level of output, if equal cost subsidies are applied, the production subsidy will create more excess burden. Thus, the additional output in P and C is expected to come only at the price of a loss in real income.

Since this empirical model departs from Miezkowski's perfectly competitive case, there are some additional factors associated with the observed change in real income. The submodels describing behavior of the national, oligopolistic chemical and primary metals sectors introduce the possibility of profits and losses. Since the price of output in these sectors is fixed exogenously (determined nationally), and is not linked to state production costs via zero profit conditions, any decline in the unit cost of production serves to enhance profits (which are transferred out of the state). In addition, the production subsidy operates directly on the firm's unit cost of production, whereas the

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[21]The 0.35% increase in L is equal to a \$268 million rise in payments to labor. At the (1977) average wage for production workers in New York manufacturing (\$10,874), this translates into 24,646 jobs.

[22]Nominal income was deflated by both the Laspeyres and Paasche cost of living indices. These represent upper and lower bounds, respectively, on the true deflator. They were virtually identical for all of the policy interventions discussed in this chapter.

[23]See Hertel (1983a) for further elaboration on the application of Miezskowski's analysis.

effect of the electricity subsidy on unit costs is dampened somewhat by factor substitution. Thus, when electricity subsidies are replaced by production subsidies, unit production costs drop, and profits in sectors P and C increase by $32.5 million and $21.0 million, respectively. Since the model assumes that supernormal profits (or losses) are absorbed by the sector's national owners, these excess profits represent a loss to the state of $53.5 million.

There are two additional factors, both of which serve to dampen the drop in real income. The first is the reallocation of output in the two oligopolistic sectors. In the production subsidy scenario, output in both P and C increases, bringing additional economic activity and income to the state. Operating in the same direction are the savings associated with reduced petroleum imports. With electricity demand dropping by 9%, the demand for imported oil to generate marginal electricity supplies drops substantially. Combined, these four factors -- increased excess burden, oligopolistic profits, increased output in C and P, and reduced oil imports -- result in a $71 million drop in real state income.

Due to the complementary relationship between labor and energy in manufacturing, the increased electricity prices paid by the manufacturing sector serve to dampen the demand for labor. With p_L fixed, this results in the loss of 20,400 jobs. When the price of labor is permitted to vary (labor supply is fixed), the effect on the wage-rental ratio depends on the size and direction of relative substitutability and composition effects. Because capital substitutes for energy, while labor and energy are complementary inputs, the former serves to dampen the wage-rental ratio as the price of electricity to manufacturing rises. The composition effect is driven by differing capital-labor intensities in the subsidized and unsubsidized sectors. The subsidized (manufacturing) sectors are relatively capital intensive so that an increase in their share of state output also serves to bid the wage-rental ratio down as well. The anticipated drop in this ratio is shown in Table 9.

No Subsidies

The final policy scenario involves elimination of the partial factor subsidy, with the proceeds being transferred, in a lump sum, to the state's consumers. (This was the shock utilized in the previous section to examine partial and general equilibrium interactions.) The drop in sector P's output is substantial (7.9%) due to the difficulty of substituting away from electricity in primary metals production. Equally interesting is the minimal decline in sector C's output because of its ability to substitute purchased fuels for electricity. The chemical sector in the state does not appear to be as sensitive to electricity prices as might otherwise be believed.

Analysis of the change in real state income is once again complicated by the non-competitive features of the model. In a fully neoclassical model, elimination of the subsidies to manufacturing would be accompanied by increased real income, attributable to more efficient utilization of the state's resources. However, the reallocation of economic activity in sectors P and C away from New York contributes to a lowering of state income. Operating in the opposite direction is the transfer of capital into the state to cover the economic losses sustained in these two sectors due to the divergence of unit production costs from exogenous output prices. These transfers are large, amounting to $187 million in the case of primary metals and $36 million for the chemicals sector. Finally, there is an income gain resulting from electricity conservation (a 10% drop in E) with the associated reduction in oil imports. The net effect of these varied forces is a $223 million increase in real state income.

Once again the complementary relationship between labor and electricity is expected to lead to a drop in state employment when the electricity subsidies are eliminated. Fixing the price of labor and resolving the model under the same no subsidy policy leads to a $555 million drop in expenditures for labor. This translates into a loss of approximately 51,000 jobs. However, only one-half of these jobs (24,800) are lost in the manufacturing sectors. The others are eliminated in the remainder of the economy, where labor intensities also drop. But these sectors face unchanging prices for electricity, purchased fuels, and (in this case) labor. Thus it is the drop in the equilibrium price of capital that encourages substitution away from the labor input.

Comparison with Other Models

The conclusion that employment drops when the electricity subsidies are eliminated (and the proceeds transferred in a lump-sum to consumers), differs sharply from the results of other models of the New York State economy. The model developed by Smith (forthcoming) is important because of the degree of disaggregation achieved (22 sectors). This enables treatment of (e.g.) the aluminum industry as a distinct sector. The costs of this disaggregation include: exogenous factor prices, endogenous commodity prices, and most significantly, the use of one of the two restrictive functional forms consistent with coefficients in an I-O table (Cobb-Douglas or fixed coefficient production functions). Thus, labor and electricity are constrained to be either substitutes in production, or to be employed in fixed proportions. This eliminates the possibility of complementarity. In addition, there is no counterpart to the oligopolistic, locational models. However, Smith's model does permit output changes in response to shifts in the pattern of final demand. At this level of disaggregation, he finds that marginal increases in income, when transferred to consumers, are spent disporportionately more on relatively labor intensive commodities. This serves to increase employment in the case with fixed coefficient production functions.

Another recent study of electricity pricing in New York State (Considine, 1981) utilizes an aggregate, Keynsian framework. As in the research reported here, Considine found labor and electricity to be complements in production in the aggregate, manufacturing sector. However, when he simulated an increase in the price of electricity paid by the manufacturing sector, this complementary relationship was dwarfed by an increase in employment in the commercial sector. The reason for this increase may be traced back to the Keynsian multiplier implicit in his macroeconomic model of the state's economy. This begins with reduced electricity consumption leading to a drop in oil imports. Assuming that the majority of these savings remains in the state, they carry with them a multiplier effect. This multiplier increases state income substantially. A large part of this additional income is spent in the commercial sector, which in turn generates employment in excess of the losses sustained in manufacturing.

This Keynsian multiplier is no different from the intraregional multiplier employed in regional economics. While it can be criticized on grounds of aggregation, it does point to an important feature of the economic environment facing state policy makers (Isard, 1982). The problematic feature of these multiplier effects, in the context of electricity pricing policy, is that the resulting increases in real income and employment are not inherently linked to "efficient" pricing. Rather, they follow from any increase in the price charged for an imported item, or a product that has a substantial imported component (e.g., oil-generated electricity). It is thus conceivable, in such a model, that inefficient taxation of electricity consumption, designed to drive the price far above marginal cost, would lead to further increases in real state income.

In contrast to Keynsian models, the general equilibrium model employed in this paper determines net exports as a residual. No distinction is made between imported and domestic products in specifying demand relationships. The state simply imports that amount which is required to meet domestic demands, based on current income. Furthermore, since the price of tradeable goods is fixed exogenously, a tax on imports will always (in a first-best world) lead to a drop in real income, because the state is driving a wedge between the actual and perceived opportunity costs of the imported product.

There are, however, two important economic effects of electricity rate reform which the general equilibrium model presented here neglects. First, the aggregate Cobb-Douglas structure of final demand which is employed does not allow for changes in output mix stimulated by widely varying income elasticities of demand across sectors. Secondly, the absence of a Keynsian consumption function in the model means that the multiplier effects, commonly employed in regional models, are absent. Empirical evidence indicates that both of these effects serve to increase employment when electricity subsidies are removed (and the proceeds transferred to consumers). In addition, the employment effects in the general equilibrium model were derived under the assumption of a fixed price of labor. For all of these reasons, the estimated drop in employment in the no-subsidy scenario should be viewed with caution, and interpreted as a bound on the likely outcome. Losses in employment will probably be smaller than the levels predicted by this general equilibrium model.

VII. CONCLUSIONS

In this paper, a model for analyzing the implications of alternative allocations of the economic rents emanating from New York State's hydropower was developed. Given the emphasis which state policymakers place on employment, one measure of the relative merit of alternative allocation schemes might be the number of jobs created. In this case, policy simulations in Section V indicate that the state would be better off selling hydropower to manufacturing at the residential and commercial rate (net of the transmission and distribution cost differential), if each manufacturing sector is provided with an equal cost labor subsidy instead. This has the added benefit of promoting energy conservation, due to the more efficient pricing of electricity.

How might such a labor subsidy be implemented? One possibility would be to institute a non-linear price schedule for electricity. While marginal rates could be tied to the opportunity cost of electricity, inframarginal costs could be tied to the firms' level of employment. That is, the labor subsidy would be provided as a reduction in the firm's electricity bill. In contrast, the model indicates that the direct effect of eliminating electricity subsidies to the manufacturing sector providing the proceeds to households, would be to decrease employment. The total employment effect will depend on the size of the composition and multiplier effects, which are not completely captured in this model.

Another concern of state policymakers involves the effect of the subsidies on the overall level of economic activity and income. Much of the economic activity in the neighborhood of the Niagara Falls and Massena hydropower facilities can be linked to the availability of cheap, reliable electricity. It was shown that replacement of electricity subsidies with equal cost production subsidies will stimulate output in these electricity intensive sectors. However, this increased output comes only at the cost of a loss in overall state income. A lump sum transfer of the hydropower rents to consumers remains the most effective means of increasing state income.

The locational models for chemicals and primary metals serve to highlight the important role played by production costs in different states, specifically electricity prices. For example, while electricity rates for aluminum companies in the Northwestern U.S. are increasing, PASNY has renewed long-term contracts with aluminum companies in New York State at very low prices. If these low prices were applied to marginal output only, it is conceivable that they might serve to encourage increased production in the state. Otherwise the subsidy in these contracts will simply be translated into increased profits for this oligopolistic sector, and perhaps lower prices for aluminum. Unfortunately, the cheap hydropower is in fixed supply, and alternatives to existing manufacturing allocations would probably provide more effective ways to stimulate economic growth.

Another conclusion is that the cheap hydropower currently provided to the chemical sector apparently does little to affect the level of national output allocated to New York State. When this subsidy is removed it is apparent that there are ready substitutes, particularly in the form of primary fuels, which serve to prevent any marked change in the unit cost of production. Combined, these conclusions indicate that it may well make sense for PASNY to monitor production costs in the rest of the country more closely, adjusting electricity prices in New York accordingly.

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